CIRCULAR 6190 NOVEMBER,

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

DEC 18 1929

INFORMATION CIRCULAR

BERYLLIUM AND BERYL

BY

ALICE V. PETAR

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BERYLLIUM AND BERYL[1]

By Alice V. Petar[2]

INTRODUCTION

Beryllium, or glucinum, is often listed as a rare element, though it probably is more abundant in the earth's crust than many of the minor metals that are ordinarily considered rather common. According to J. H. L. Vogt,[3] between 0.01 and 0.001 per cent of the entire lithosphere is beryllium. It is not a new metal, for it has been known for more than a hundred years, but even yet it has not been put to work commercially except to an extremely limited extent. Since beryllium is very light and exceptionally hard and strong, many believe that it is destined to share with magnesium and aluminum in the fast-growing demands for light metals to be used in the construction of air craft. Active interest has been aroused in the possibilities of beryllium, and the Bureau of Mines has received numerous inquiries with regard to the metal and more especially with regard to sources of beryl.

The mineral beryl, which seldom contains more than about 5 per cent of the element, is the only recognized ore of beryllium. It is a common accessory in pegmatite veins and is also found in clay slate and mica schist, but hitherto only the gem varieties, including emerald and aquamarine, have been actively sought. In several localities, however, ordinary beryl is produced as a by-product in mining mica and feldspar, and often beryl has accumulated on the dumps because no buyer could be found. Only within the last two or three years has there been an active demand for the mineral, even in ton lots, and as yet requests for carload shipments are extremely rare. Considerable interest has been awakened, nevertheless, in the possibility of opening deposits that will yield beryl in substantial quantity.

Changes are taking place rapidly in activities concerning beryllium. The present circular is presented with no claims that it records all of the latest developments. It represents merely a summary of information which has

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1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6190."

2/ Rare metals and nonmetals division, U. S. Bureau of Mines.

3/ Vogt, J. H. L., Problems in the Geology of Ore Deposits. Trans. Am. Inst. Min. and Met. Eng., vol. 31, 1901, p. 128.

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accumulated in the files of the Bureau of Mines and which, it is hoped, will prove useful to those interested in the production or utilization of this newest of the light metals.

BERYLLIUM

DESCRIPTION AND PROPERTIES

The metal beryllium, or glucinum, has aroused the interest of many investigators, who have worked out various processes of extracting it from its ores. Beryllium is very light, having about the same specific gravity as magnesium, and is almost as hard as quartz. It will scratch glass and it takes a high polish. Early investigators claimed that beryllium was malleable and could be easily forged and cold-rolled into sheets, but later studies do not support these claims. While it is possible that absolutely pure beryllium, if obtained, might have the qualities formerly attributed to it, investigations conducted at the Bureau of Standards[4] with metal of 98.7 per cent purity indicated the contrary. This product was described as "coarsely crystalline, reminding one of antimony or bismuth, * * * hard and brittle, and apparently incapable of being wrought cold." It is further stated that more recently metal of more than 99.5 per cent purity has been produced, some lots of which are semimalleable cold and can be rolled hot into a thin sheet. The melting point of beryllium has been determined as 1,285° C., or a little above that of manganese.

USES

Considerable research has been carried on in this country and abroad toward the development of uses for beryllium, but the use of the metal is still in the experimental stage and its commercial applications are definitely limited until such time as the cost of extraction, now almost prohibitively high, can be reduced. From time to time there have been items in the press describing it as the new and and logical light metal for aviation use, and the Materials Subcommittee of the National Advisory Committee for Aeronautics is planning to arrange for tests of beryllium for use in airplane construction. Nevertheless, to date, this use has not materialized, and the Siemens-Halske Co. in Germany, which has been particularly diligent in its studies of the properties and possible uses of the metal, has concentrated its efforts chiefly upon alloys containing small quantities of beryllium with heavy metals, such as iron, copper, and nickel. It is claimed[5] that -

> * * * beryllium hardens iron to a great extent; by an addition of only 2 per cent the hardness is increased from about 100 to 300. By means of heat-treatment this hardness can be increased to 500 to 600, so that the iron is as good as the 'C' steels. Beryllium-iron alloys with more than a 4 per cent beryllium content can not even be rolled, either cold or hot. But such alloys can be improved so that hardnesses are obtained which are only very slightly below that of hardened steel.

4/ U. S. Bureau of Standards, Light Metals and Alloys - Aluminum, Magnesium (with bibliography). Circular 346, 1927, pp. 314-315.

5/ Illig, Kurt, Production and Utilization of Beryllium Metal. Zschr. Angew. Chem., vol. 40, 1927, pp. 1160-1163. Translation, Foote-Prints, vol. 1, No. 4, 1928, pp. 30-33.

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> The alloys of beryllium with copper and nickel merit special attention. * * * The resistance properties of such alloys with 2 to 3 per cent of beryllium in an untreated condition are about equal to those of a high grade annealed bronze. However, by means of a suitable treatment, one obtains strengths which are far beyond those of a double-spring, hard, rolled or drawn bronze, while the expansion values are about equal. A special superiority of the beryllium-copper and beryllium-nickel alloys over bronze is that they can be worked as desired while in the untreated condition, to be hardened by proper treatment after completion, while bronze already receives its great hardness and strength during the cold shaping, and no further shaping is possible while in this condition. As compared to the carbon-steels, these alloys furthermore show a great resistance to corrosion. They will, therefore, find application in technology wherever in addition to this almost universal requirement, the highest demands in respect to grinding, stamping, spring making, etc., come under consideration.

In Great Britain, beryllium has been studied at the National Physical Laboratory under a committee of the Department of Scientific and Industrial Research. Efforts have been made to prepare the metal in a purer, and if possible, more ductile form. Small quantities of beryllium metal have become available in the course of the investigation, and an attempt has been made to study the alloys of iron and beryllium.6/

In the United States the metal has been produced on a semi-commercial scale by the Beryllium Corporation of America at Cleveland. While this company has devoted some attention to the heavy alloys, chiefly those of beryllium with gold and silver, its chief interest has been with the beryllium-aluminum alloys. Menahem Merlub-Sobel, formerly chemical engineer of the Beryllium Corporation of America, states7/ that the addition of beryllium to aluminum increases its strength and resistance to corrosion, and that an alloy containing 70 per cent beryllium and 30 per cent aluminum "exhibits materially greater resistance to salt water and air corrosion than any other of the light alloys."

Beryllium has been used in this country and abroad in X-ray apparatus. Another use which may grow considerably is for electrodes in connection with neon signs.

Experiments have been conducted at the University of Pittsburgh8/ on over 80 different glasses in which beryllium oxide replaced calcium oxide or magnesium oxide. It was found that beryllium glasses are somewhat more refractory than magnesium or calcium glasses and that beryllium glass is much harder than calcium or magnesium glass. Results so far obtained indicate that beryllium glasses warrant further study.

6/ Chemical Age, The Search for New Alloys. Vol. 18, April 7, 1928, p. 316.
7/ Sobel, Menahem Merlub, Beryllium. Metals and Alloys, vol. 1, Aug., 1929, pp. 69-70.
8/ Lai, Chi Fang, and Silverman, Alex, Beryllium Glass. Jour. Am. Ceram. Soc., vol. 11, 1928, pp. 535-41.

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HISTORY

In 1797, Haüy, a mineralogist, found that the minerals beryl and emerald have the same physical structure, hardness, and specific gravity, and at his suggestion, L. N. Vauquelin proved that these minerals are identical chemically. In making the analysis he also discovered that they contain an oxide which at first he took to be alumina, but upon closer study found that it had several distinct properties. It was precipitated from its potassium hydroxide solution by boiling; its salts had a sweet taste; its hydroxide was soluble in dilute ammonium carbonate and formed in alum.

In first describing the new element, Vauquelin did not give it a name, but referred to it as "the earth of beryl." The editors of the Annales de Chimie suggested the name of "glucine," meaning sweet, because of the taste of its salts, and in a later article Vauquelin adopted their suggestion. H. F. Link took exception to the use of this name because of its resemblance to "glycine," which was already in use, and M. H. Klaproth, calling attention to the fact that the salts of yttrium earths were also sweet, proposed "beryllerde" as a preferable name. For a time the element was referred to as "beryllerde" in Germany and "glucine" in France.

In 1828 F. Wöhler isolated the metal and called it beryllium, and subsequently the names glucinum and beryllium have been used indiscriminately. Both names have their advocates.

The early history of beryllium has been described by Parsons[9/] as follows (original references omitted):

> Following the discovery of the element, Vauquelin studied and announced the properties of some of its chief compounds. In 1828 the metal itself was produced in a very impure form by both Wöhler and Bussy. Awdejew added materially to the literature of the subject and made the first determinations of the atomic weight that have any claim to accuracy. Weeren and Debray also carried on extensive investigations of the metal, its atomic weight and chief compounds. Joy undertook an extended research on the preparation of its compounds from beryl and published a fairly complete bibliography of the subject to his day. Atterberg and Nilson and Pettersson in the years between 1873 and 1885, made large additions to the chemistry of beryllium, and during these years a long, earnest, and interesting discussion, which had begun as early as Awdejew's time, was carried on by Nilson and Pettersson, Humpidge, Reynolds, Hartley, Lothar Meyer, Brauner, and others regarding the valency of beryllium and its place in the periodic system. The discussion has continued up to the present day, but was in reality settled when Nilson and Pettersson determined the vapor density of the chloride, and Humpidge showed that at high temperatures the specific heat of beryllium approached very closely to normal. Krüss and Moraht made a redetermination of the atomic weight in 1890, and between the years 1895 and 1899, Lebeau published an important series of articles which are summed up by him in one of the very best articles on beryllium and its compounds. Urbain and

9/ Parsons, C. L., The Chemistry and Literature of Beryllium. Chem. Publishing Co., Easton, Pa., 1908, p. 2.

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Lacombe discovered the remarkable basic salts of the acetic acid series and Parsons redetermined the atomic weight by new methods and studied many compounds, especially the so-called basic salts of some of the earlier writers. Numerous other investigators * * * have also contributed to the chemistry of beryllium.

In 1913 Fichter and his pupils prepared beryllium in sufficient quantity to study its properties, employing the method of M. Lebeau, and obtained a 98 per cent pure metal.

In 1916 Oesterheld[10] published an important experiment. He studied more particularly the equilibrium diagrams of the alloys beryllium-iron, beryllium-aluminum, beryllium-copper, and beryllium-silver.

In 1921 Stock and Goldschmidt, in Germany, with the cooperation of Priess and Praetorius, obtained metallic beryllium for the first time in the form of large buttons, directly from a fused electrolyte. Their investigations are described in some detail by Illig[11], who says, in part:

> * * * Before starting their experiments, Stock and Goldschmidt made an effort to find a method by which all of the limiting conditions would be eliminated. They felt that the electrolytic separation of beryllium (melting at 1,285° C.) from a fused salt mixture could only be possible if a salt be used, which at this temperature either did not evaporate at all, or at least did so only slightly. On the other hand, to avoid an unusually high potential drop between the electrodes, the salt must also possess at this temperature a very low viscosity; and furthermore, the anions must be easily separated or removed from the electrolyte. It is only in this manner that the separated metal might be prevented from remaining in, or being redistributed in, the surrounding fused salt mass.
>
> Investigations have shown that these conditions are fulfilled in general by the double fluorides of beryllium with sodium and barium. The barium-beryllium fluoride has an appreciable viscosity around 1,300° C., but also has the advantage of being only slightly volatile at this temperature range; it has an appreciable dissociation within this range. The sodium-beryllium fluoride is strongly dissociated even at relatively low temperatures. This, therefore, offers a means of obtaining an electrolyte possessing a good conductivity. It has only one disadvantage, namely, that at very high temperatures the separated beryllium metal may be volatilized in appreciable quantities.
>
> If the electrolysis is started with the sodium-beryllium fluoride, and with rising temperatures, some barium-beryllium fluoride is added in increasing amounts, there is obtained a useful mixture of the double salts for every temperature interval. When the final metal separating temperature of 1,300-1,350° C. is reached, it is not difficult to continue the electrolysis for many hours, provided suitable

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10/ Oesterheld, , Ueber den Schmelzpunkt und die Schmelzwaerme des Beryllium. Ztschr. anorg. Chem. vol. 97, 1916, p. 1.

11/ Illig, Kurt, The Production and Uses of Beryllium. Trans. Am. Electrochem. Soc., vol. 54, 1928, pp. 53-64.

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additions of both double salts are made from time to time.

Stock and Goldschmidt protected this general method of procedure by letters patent in all large countries. They realized, however, that much additional work was necessary before all of the details for the continuous production of large quantities of beryllium would be established.

In order to study the problems on the broadest basis, the foremost German manufacturers organized a "Beryllium Research Institute" in 1923, under the chairmanship of the Siemens and Halske A. G., of Berlin. It was the aim of this institute to make a systematic study of the fundamental Stock-Goldschmidt method in all of its details and to determine whether or not it was possible to produce beryllium metal in commercial quantities from fused electrolytes. * * * In 1926 the Institute felt convinced that in the Stock-Goldschmidt method there was a means by which a commercial production of beryllium metal might be expected. At the same time the commercial applications of this metal were studied.

The Stock-Goldschmidt process was developed and improved by the Siemens & Halske, A. G., and it is reported that an experimental plant capable of producing about a ton of beryllium metal yearly is nearing completion.

PRICES

Beryllium is quoted in the United States at $200 per pound, and shipments are made chiefly from small stocks manufactured in 1927 or earlier. As in all metallurgical operations, the production of the metal on a laboratory or semicommercial scale is much more costly than it would be in large lots. Menahem Merlub-Sobel[12] estimates that the metal could be manufactured "at less than $5 per pound if, and when, the market absorbed 100 tons or more per annum; this without crediting the metal with certain by-products obtained in the course of its manufacture."

Kurt Illig[13] has predicted that when the production of the Siemens-Halske Co. reaches 1 ton of beryllium per year, the price will be $35 to $40 per pound ($75 to $90 per kilogram), and that should the sale of the metal increase to 100 metric tons a year it may be possible to cut the price by two-thirds or to $12 or $13 a pound.

BERYLLIUM MINERALS

Beryllium is present in a great number of granitic rocks and to a minor extent in clay slate and mica schist, in the form of aluminates, silicates, phosphates, borates, etc. Beryl, which appears to be by far the leading, if not the only ore of the metal, is a common accessory of pegmatite veins. It alters to mica and kaolin, and the beryllium oxide thereby released

12/ Work cited, p. 3.
13/ Illig, Kurt, The Production and Uses of Beryllium. Trans. Am. Electrochem. Soc., vol. 54, 1928, pp. 53-64.

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may reappear as a constituent of secondary minerals, notably bertrandite, herderite, and beryllonite.

Due to the lack of a market for any but the gem varieties of beryl, there has been no incentive until recently to develop deposits. Until a year or two ago the total output in the United States probably did not exceed 10 or 15 tons a year and even now (1929) demand is limited to occasional shipments in less than carload lots.

BERYL

Beryl is a complex silicate of aluminum and beryllium. When pure it has the formula $3BeO.Al_2O_3.6SiO_2$ and contains 14 per cent beryllium oxide, but often the beryllium is replaced by other oxides, such as calcium, iron, chromium, potassium, sodium, or cesium. In color beryl varies from white or colorless to green, blue, yellow (amber), and even red, but usually it is some shade of green. Clear transparent crystals are cut as gems. The deep green variety, the color of which is attributed to the presence of a little chromium, is the emerald[14] which is worth more than the diamond. Aquamarine, a sky-blue or greenish-blue variety, is also a precious stone. Beryl is about as heavy as quartz, sometimes a little heavier (specific gravity, 2.63 to 2.8), but its outstanding characteristic is its hardness (7.5 to 8). It is harder than quartz or tourmaline and practically as hard as topaz, from which it differs in that it has no distinct cleavage. It crystallizes in hexagonal prisms ranging in size from mere thread-like pieces to huge crystals many feet in length and weighing several tons. Occasionally it occurs in large columnar or granular masses.

Uses of Beryl

In addition to its potential value as a source of beryllium metal, ordinary beryl may have other uses, notably as a substitute for feldspar in the manufacture of porcelain. This use has been described by W. M. Myers[15] as follows:

> Investigations carried on by the Bureau of Standards (Bleininger, A. V., and Riddle, F. H., Special Spark-plug porcelains. Jour. Am. Ceram. Soc., vol. 2, July, 1919) have shown that when beryl is substituted for feldspar in the manufacture of porcelain in amounts varying from 25 to 45 per cent of the total mixtures, the other components being silica and clays, a product is obtained which displays a very high electrical resistance and low thermal expansion. This porcelain is therefore considered a very promising material for electrical uses. Due to the scarcity of beryl there has been no commercial production of this type of porcelain.

14/ The so-called oriental emerald is a variety of corundum, an aluminum oxide.

15/ Myers, W. M., New Uses of Nonmetallic Minerals. Rep. of Investigations, Serial 2587, Bureau of Mines, 1924, p. 5.

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Occurrences of Beryl

United States.

Good emeralds have been found in Massachusetts and in North Carolina (Alexander County, especially from Stony Point). Aquamarines and other gem specimens have been obtained at Paris and Stoneham, Me.; Mount Antero, Colo., and several places in North Carolina. The best emeralds, however, are mostly imported. The world supply comes from Colombia, British India, Brazil, Siberia, Australia, and (recently) South Africa.

Occurrences of beryl, as described by the United States Geological Survey[16], may be summarized as follows:

Alabama:

Coosa County: Crystals suitable for gems have been found near Rockford and Hissop.

California:

Riverside County: Fine yellow and green beryls occur at Coahuila, and rose crystals near Hemet.

San Diego County: Aquamarine variety is mined intermittently at Pala, Rincon, Mesa Grande, and Ramona; yellow, green, and blue crystals occur in the Palomar Mountains 9 miles southeast of Pala.

Tuolumne County: Jamestown (reported).

Colorado:

Boulder County: Near Glendale.

Chaffee County: Occurs near top of Mount Antero; color varies from light blue to deep aquamarine green; fine gems, worked intermittently.

Clear Creek County: Georgetown.

Fremont County: East Gulch, 6½ miles north of Texas Creek; mined, few gems cut.

Jefferson County: Near Creswell.

Park County: Buffalo Mountain.

16/ Schrader, F. C., Stone, R. W., and Sanford, Samuel, Useful Minerals of the United States. U. S. Geol. Surv. Bull. 624, 1916, 412 pp.

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Connecticut:

Fairfield County: At Branchville.

Litchfield County: Gem golden beryl and aquamarine were mined with mica and feldspar 6 miles north of New Milford.

Middlesex County: Abundant in the pegmatite at several quarries in Middletown, Portland, Chatham, and Haddam; gem aquamarine found in some of these, especially in Portland and Haddam.

New Haven County: Found in Southford quarry.

Georgia:

Rabun County: Beck beryl mine 7 miles east of Clayton. Large flawed crystals in pegmatite contain clear portions suitable for cutting.

Maine:

AQUAMARINE:

Kennebec County: At Winslow, with mica and fluorite in cassiterite vein.

Oxford County: French Mountain, town of Albany; Bunton mine, town of Newry; Mount Mica, town of Paris; associated with corundum, town of Greenwood; Sugar Hill and Harndon Hill, town of Stoneham.

Sagadahoc County: At Topsham feldspar quarries.

CESIUM BERYL:

Androscoggin County: Berry quarry, town of Poland.

Oxford County: Town of Hebron; on Dudley farm, town of Buckfield.

GOLDEN BERYL:

Oxford County: Edgecomb Mountain, town of Stoneham, and Speckled Mountain, town of Peru.

Opaque varieties common in pegmatites, notably:

Androscoggin County: Apatite Hill, town of Auburn.

Hancock County: In cassiterite-bearing granite at Catharine Hill.

Oxford County: Noyes mine, town of Greenwood.

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Massachusetts:

Worcester County: At Royalston, best locality in State, blue and yellow gem quality, worked intermittently.

Franklin County: At Northfield.

Hampden County: Blandford.

Hampshire County: Chesterfield, Goshen, and Norwich.

EMERALD:

Hampshire County: Reported specimens found at Chesterfield and Goshen.

New Hampshire:

Common in pegmatite ledges of Cheshire, Grafton, Merrimack, and Sullivan Counties.

Cheshire County: Large crystals found in Nim's mica mine, town of Sullivan; both gem aquamarine and golden beryl have been mined at Island mica mine in town of Alstead; gem and specimen beryl found in town of Roxbury.

Grafton County: Large crystals found at Standard mica mine near Orange; at De Mott mine, Kilton mine, and Alger Hill mine near Grafton Center; Horse Hill near Grafton; Wilcher & Pillsbury mine in town of Wentworth; and at New Haven mica mine, town of Alexandria; gem aquamarine and golden beryl have been mined at Reynolds mine on Sanders Hill and at Playter mine in Springfield Mountains, south of Grafton.

Merrimack County: Plentiful on Stuart Hill, 2 miles west of Danbury.

Sullivan County: Crystals measuring 1 inch to 2 feet in diameter found at Beryl Mountain near South Acworth.

New Mexico:

Santa Fe County: Near Santa Fe, a few crystals of fine quality found in the gravels, not worked.

North Carolina:

Alexander County: Mined at Hiddenite-Emerald mine.

Burke County: Near Burkmont in South Mountains.

In mica mines in Alexander, Iredell, Mitchell, and Yancey Counties.

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AQUAMARINE:

Alexander County: Mined at Hiddenite and Ellis mines, near Hiddenite.

Burke County: Has been found in South Mountain.

Jackson County: Mines several miles south of Cashiers.

Macon County: Mined at head of Tessentee Creek.

Mitchell County: Mined at Wiseman and other mica mines.

Yancey County: In Ray and other mica mines.

Pennsylvania:

Chester County: Union township, near Northrop and Unionville, has yielded hundreds of pounds of crystals.

Delaware County: Deshong's quarry at Leiperville; the Shaw-Ezra quarry at Chester; Avondale quarry near Media; many localities in Concord, Marble, Middletown, and Upper Province townships; Linwood, occasionally found.

Philadelphia County: Fairmount Park, Germantown, Logan, Mount Airy, and Shawmont have all produced gem specimens.

South Carolina:

Anderson County: A few crystals sufficiently clear to be cut for gems have been found at McConnel Place, 3 miles north of Anderson. Occurs at numberous points along the Anderson-Spartanburg zone. Cut for gems.

South Dakota:

Custer County: Large crystals and masses occur in pegmatites with tin amd mica.

Pennington County: In pegmatites near Keystone.

Utah:

Tooele County: About 35 miles southwest of Simpson Springs, Ibapah Mountain.

Virginia:

Amelia County: Amelia mica mines.

Henry County: In pegmatite near Axton.

Rockbridge County: With cassiterite in Irish Creek area.

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In the spring of 1923, in order to obtain an approximate idea as to the beryl resources and production of the United States, the Bureau of Mines addressed questionnaires to the mica and feldspar producers of the country. The replies indicated that the only production of any consequence was from the Black Hills of South Dakota, New York, Maine, and New Hampshire, and at that time several of the producers had stocks on hand for which they were desirous of finding a market.

Maine:

Occurrences in Maine are described in some detail by Bastin[17], who summarizes the beryl resources of the State, as follows:

> * * * Opaque crystals are quite common in most of the coarser pegmatite deposits of Maine, where they occur as more or less regular prisms embedded in the solid pegmatite. Some of these reach remarkable dimensions: one found in the Maine Feldspar Company's quarry at Mount Apatite in Auburn was described as having a diameter equal to that of a hogshead. One from the Noyes gem mine in Greenwood, Oxford County, was so large that a man could barely reach around it with his arms. * * *
>
> Emeralds are of rare occurrence in the pegmatite deposits of Maine. One crystal of light grass-green color embedded in quartz was observed by the writer at the Dunton gem quarry in Newry, Oxford County. It was a prism half an inch across and 1½ inches long but was so badly fractured as to be valueless for gems. * * *
>
> The light-blue to sky-blue and light-green transparent varieties of beryl known as aquamarine are more abundant than any of the other gem varieties of beryl found in Maine, and specimens of remarkable size and beauty have been obtained. * * * Most of the gem material has come from Oxford County. Some has been obtained from what is known as the Emmons mine in the southwestern part of Greenwood, from French Mountain in Albany, Sugar Hill in Stoneham, and Lovell, Bethel, and other towns. A fine sea-green aquamarine weighing about 7 carats was found near Sumner. Recently some good gems have been obtained on the Dudley farm in Buckfield. * * *
>
> Beautiful transparent golden-yellow beryls have been obtained in the pegmatites at various points in Oxford County, at Edgecomb Mountain in Stoneham, in Albany, and recently good gem material of a straw yellow has been obtained from the west side of Speckled Mountain in Peru. They are mined sporadically by gem collectors, mostly from small prospects. * * *
>
> A colorless to bluish-white or pinkish-white variety of beryl containing a small percentage (1.66 per cent to 3.6 per cent) of oxide of cesium was first discovered in Hebron, Oxford County, but has since been found to occur at a number of other pegmatite localities in the western part of the State, notably at Mount Mica in Paris, at the Dudley farm in Buckfield, Oxford County, and at the feldspar quarry

17/ Bastin, Edson S., Geology of the Pegmatites and Associated Rocks of Maine. U. S. Geol. Surv. Bull. 445, 1911, 152 pp.

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of Mr. A. R. Berry in Poland, Androscoggin County. Generally it occurs in somewhat irregular masses in the solid pegmatite, but in some occurrences shows regular crystal forms. When cut it makes a stone of high brilliancy which as a night stone is considered by some to be superior to many diamonds. It is valued chiefly because of its resemblance to the diamond.

There is also an interesting occurrence of beryl at the Bumpus Quarry, Bethel, Me., in which large crystals have been exposed.

New York:

Beryl, associated with feldspar, occurs at Bedford, Westchester County. The deposit is one of the principal sources of beryl in the East.

South Dakota:

The largest potential source of beryl is apparently in the Black Hills of South Dakota. The deposits in that region are described as follows:18/

> Beryl occurs in greater or less amounts in nearly all of the pegmatite bodies of the southern Black Hills, and is also found in some of those of the Nigger Hill area in the northern Hills. Excellent crystals and crystal groups have been found in the Crown mica mine near Custer. It also occurs in the White Spar and New York mines, although in the latter it is somewhat impure, having much included quartz, feldspar, and tourmaline. Beryl occurs in considerable abundance in the pegmatites near Keystone. All four of the larger bodies show it, the Etta, Hugo, Peerless, and Ingersoll. At the Ingersoll may be seen at the present time what is probably the largest beryl crystal ever uncovered. A section across the prism is exposed here which is 46 inches in diameter. The length of the crystal is not known, as it has never been fully exposed. The Beryl Mica lode at Pringle, operated by the Dakota Feldspar Company, contains much beryl which gives promise of considerable commercial importance.
>
> * * * The value of the entire production from the Hills to date is probably less than $2000.

High freight rates have proved a handicap in marketing the South Dakota material. On full carloads a rate of $17 a ton can be obtained in New York, but on less than carload lots -- even shipments of 10 tons or more - a rate of $50 a ton has been charged.

Foreign Countries.

Africa:

Two companies are reported to be actively interested in the production of beryl. The Beryl Mining Co. is working the Somerset mine in the Leydsdorp district, eastern Transvaal, and Beryllium, Ltd., has recently been

18/ Connolly, Joseph P., and O'Harra, Cleophas C., The Mineral Wealth of the Black Hills. South Dakota School of Mines Bull. 16, 1929, pp. 254-5.

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organized for the purpose of working claims in Namaqualand. According to W. E. Bleloch, chairman of the Beryl Mining Co.19/, the mine has been "steadily producing from 300 to 350 pounds of crystals per week from a total gross tonnage mined of approximately 300 tons." The material mined has apparently been marketed entirely as gem material, although Mr. Bleloch stated that the board was making inquiry with regard to the market value of beryllium metal.

The recently discovered deposits in Namaqualand have attracted considerable attention in the technical press, and it is stated20/ that preliminary excavating has resulted in the recovery of about 15 tons of beryl, averaging over 15 per cent BeO.

Brazil:

Crystals of beryl varying from 20 centimeters to 2 meters in circumference occur in the pegmatites of Minas Geraes and Bahia. Some of the mineral is in the form of aquamarine, and one very large specimen weighing 110.5 kilograms was found in Marambaia.21/

Canada:

Beryl deposits in Canada are located in Renfrew County, Ontario, about 150 miles northeast of Toronto, near the village of Quadville; and in the Abitibi region of the western part of the Province of Quebec, 20 miles southwest of Amos on the Canadian National Railway22/. No definite information is at hand concerning the extent of these deposits, but the article referred to indicates that the deposit in Renfrew County gives promise of a large tonnage of high-grade beryl.

Colombia:

The emerald deposits, 75 kilometers from Muzo, are well known and have long been a source of gem stones.

India:

Beryl crystals are found in the mica mines in Nellore, varying in size from tiny crystals less than half a centimeter to those measuring a foot in diameter. V. S. Swaminathan23/ estimates that from 3 to 5 tons of beryl per year would be available. Beryl also occurs in the mica mines in Behar.

19/ South African Mining and Engineering Journal, The Position and Prospects of Beryl Minings. Vol. 40, April 27, 1929, pp. 224.

20/ South African Mining and Engineering Journal, Remarkable Beryl Discovery. Vol. 40, June 22, 1929, pp. 477-80.

21/ Moraes, L. J. de, Nota sobre algunas jazidas de beryllo e mica do valle do Rio Doce, Estado de Minas Geraes. Ministerio da Agricultura, Industria e Commercio, Servico Geologico e Mineralogico do Brasil, Boletin No. 18, 1926, pp. 23-32.

22/ Bulletin of the Imperial Institute of Great Britain, Beryl in Canada. Vol. 24, No. 3, 1926, pp. 569-70.

23/ Swaminathan, V. S., The Mode of Occurrence and Chemical Composition of Beryl from Nellore, With a Note on its Industrial and Chemical Applications. Trans., Min. Geol. Inst. India, vol. 22, pt. 3, Oct., 1928, pp. 258-267.

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New South Wales:

Beryl occurs associated with tinstone at Elsnore, Mole Tabeland; with feldspar, quartz, and mica at Ophir, Wellington Co.; at Shoalhaven River, east of Bungonia, and in alluvial deposits at Emmaville, Kangaroo Flat, Tungha Copes Creek, and Scrubby Gully.[24]

Siberia:

Transparent beryls occur near Ekaterinburg and Miask, and in the mountains of Adun-Chalon, in Eastern Siberia; some of the crystals exceed a foot in length. It is understood that the Soviet Government has for some time been carrying on active prospecting in various districts in the Urals, and Schlenzig[25] believes that the Siberian mining of beryl will be the decisive factor in forming the price of beryllium metals.

United Kingdom:

Beryl has been found in the Mourne Mountains of County Down; at Killiney, near Dublin; Rubislaw near Aberdeen; and at St. Michael's Mount, Cornwall.[26]

Minor Minerals

In addition to beryl, a number of other minerals are known which contain appreciable quantities of beryllium, though the minerals themselves do not occur in quantities sufficient to make them of economic interest as sources of beryllium. Negru[27] has summarized these minor minerals of beryllium as follows:

Bertrandite. A beryllium silicate of the composition $4BeO.2SiO_2.H_2O$ (50.3 per cent SiO_2, 42.1 per cent BeO, 7.6 per cent H_2O). It is found in Bohemia, France, and in the United States (Colorado, Maine, Virginia).

Colorado:	Mount Antero, Chaffee County.
Maine:	Stoneham, Oxford County.
Virginia:	Amelia Court House, Amelia County.

Beryllonite. A sodium-beryllium phosphate of the composition $NaBePO_4$ (P_2O_5, 19.7 per cent BeO, 24.4 per cent Na_2O). It is found in the United States at Stoneham, Oxford County, Maine.

24/ Bulletin of the Imperial Institute of Great Britain, The Source and Industrial Uses of Beryllium Compounds. Vol. 12, 1914, pp. 613-615.
25/ Schlenzig, J., Beryllium: Occurrence and Production Costs. Metal Industry (London). vol. 35, Aug. 2, 1929, pp. 107-8.
26/ Bulletin of the Imperial Institute of Great Britain, The Source and Industrial Uses of Beryllium Compounds. Vol. 12, 1914, pp. 613-615.
27/ Negru, J. S., Glucinum. Chem. and Met. Eng., vol. 21, 1919, pp. 353-359.

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Chrysoberyl. A beryllium-aluminum oxide of the composition $BeO.Al_2O_3$ (80.2 per cent Al_2O_3, 19.8 per cent BeO). It is found in Brazil, Ceylon, Ireland, Moravia, Siberia, and the United States (Colorado, Connecticut, Maine, New Hampshire, and New York).

Colorado:	6 miles west of Sedalia, Fremont County.
Connecticut:	Haddam, Middlesex County.
Maine:	Newry and Stoneham, Oxford County.
New Hampshire:	New Orange Summit, Grafton County.
New York:	Greenfield, Saratoga County.

Danalite. A complex mineral of the composition $(Be, Fe, Zn, Mn)_7 Si_3O_{12}S$ with about 14 per cent BeO. It is found in the United States (Colorado, Massachusetts, New Hampshire).

Colorado:	West Cheyenne Canyon, El Paso County.
Massachusetts:	Essex County: Rockport, Cape Ann., Gloucester.
New Hampshire:	Bartlett.

Gadolinite. A complex silicate of beryllium, iron and yttrium, of the composition $2BeO.FeO.2Y_2O_3.2SiO_2$ (23.9 per cent SiO_2, 51.8 per cent Y_2O_3, 14.3 per cent FeO, 10 per cent BeO). It is found in Greenland, Ireland, Norway, Silesia, Sweden, and the United States (Arizona, Colorado, Texas).

Arizona:	Mohave County, in cliffs, 30 miles south of Hackberry, and near Kingman, about 6 miles west of Chim Lee Valley and 2 to 4 miles south of the Utah line.
Colorado:	Douglas County, Devil's Head Mountain; Washington County, Akron.
Texas:	Burnett County; Llano County: Baringer Hill. (Here are found crystalls of gadolinite weighing up to 60 pounds.

Helvite. A complex silicate of the composition $(Mn,Fe)S.3(Be,Mn,Fe)_2 SiO_4$, with about 13.5 per cent BeO. It is found in Finland, Hungary, Norway, Saxony, and the United States (near Amelia Court House, Amelia County, Virginia.

Herderite. A fluophosphate of calcium and beryllium of the composition (CaF)BePO (43.8 per cent P_2O_3, 15.4 per cent BeO, 34.6 per cent CaO, 5.9 per cent F). It is found in Saxony and the United States (Maine: Hebron and Stoneham, Oxford County, and Auburn, Androscoggin County).

Phenacite. A beryllium orthosilicate of the composition $2BeO.SiO_2$ (54.45 per cent SiO_2, 45.55 per cent BeO). It is found in the Urals (near Ekaterinsburg), France, Mexico (near Durango), Switzerland and the United States (Colorado, Maine, Virginia).

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Colorado:	Chaffee County, Mount Antero and Devil's Head; El Paso County, Crystal Park, 2 miles southwest of Manitou; Teller County, Topaz, Butte, near Florissant, and at Cripple Creek in the Gold King Mine.
Maine:	Near Stoneham, Oxford County.
Virginia:	Amelia Court House, Amelia County.

Euclase. A beryllium-aluminum silicate of the composition $2BeO.2SiO_2.Al_2O_3.H_2O$ (41.3 per cent SiO_2, 35.2 per cent Al_2O_3, 17.3 per cent BeO, 6.2 per cent H_2O). It is found in Brazil (Province of Mines Geraes), Ural (Orenburg District) and in the Austrian Alps.

Eudidymite. A beryllium-sodium silicate of the composition $H_2O.Na_2O.2BeO.6SiO_2$ (73.4 per cent SiO_2, 10.2 per cent BeO, 12.7 per cent Na_2O, 3.7 per cent H_2O). It is found in southern Norway, near Langesund fiord.

Hambergite. A beryllium borate of the composition $4BeO.B_2O_3.H_2O$ (53.25 per cent BeO, 36.72 per cent B_2O_3, 10.03 per cent H_2O). It is found in southern Norway, near Langesund fiord.

Leucophane. A complex silicate of the composition $NaF.3BeO.3CaO.5SiO_2$ with 10.3 per cent BeO. It is found in the southern part of Norway, near Langesund fiord.

Meliphanite. A complex silicate, somewhat similar to leucophane, of the composition $NaF.2BeO.2CaO.3SiO_2$ with 13.1 per cent BeO. It is found in Norway, near Langesund fiord.

Trimerite. A complex silicate of the composition $(Mn,Ca)_2SiO_4.Be_2SiO_4$ with 16.6 per cent BeO. It is found in Sweden, at Vermland.

Markets and Prices

In recent months there has been some inquiry for beryl from abroad, and it is understood that foreign buyers have been paying in the neighborhood of $60.00 a short ton f.o.b. New York. However, there can not be said to be a regular market price for beryl in this country, and sales are probably a matter of bargaining. As stated before, high freight rates ($17 a ton on full carloads and $50 a ton on less than carload lots) have made it difficult to market South Dakota material in the East. The demand in the United States, however, is small, -- all less than carload lots, -- and much of the beryl marketed in the East has come from New York State.

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